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LEAF-SPOT, A DISEASE OF THE SUGAR BEET.

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INTRODUCTION.

Leaf-spot is one of the best known and most widely distributed diseases of the sugar beet (fig. 1). It is caused by a well-defined fungus (mold) known by the name of *Cercospora beticola*.[1] These fungi (molds) are low forms of plants that depend for their existence upon other forms of plant or animal life. In this particular case the leaf-spot fungus penetrates the tissues of the leaf and leaf stem of the beet and feeds upon the material that the beet plant has prepared for its own growth and development. It is plain, therefore, that any considerable number of these fungous plants feeding upon a single beet plant must necessarily retard its growth. Furthermore, since the sugar of the beet is all made in the leaves of the beet plant, any appreciable injury to the leaf surface must reduce the sugar-making ability of the infested plants. Consequently, leaf-spot tends to reduce both the tonnage and the sugar content of the beets affected.

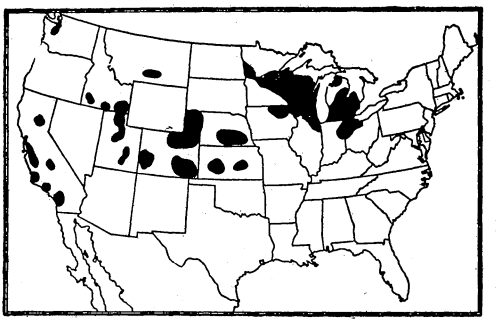

FIG. 1.—Sketch map of the United States, the black spots showing areas of occurrence of sugar-beet leaf-spot.

The amount of injury done by the fungus in any particular field of beets will depend upon the number of fungous plants that attack

[1] Another leaf-spot of the sugar beet, due to *Phoma betae*, is prevalent in some sugar-beet areas, but it is not nearly so common or as destructive as Cercospora and is easily distinguished from it. The term leaf-spot used in this bulletin refers to Cercospora leaf-spot unless otherwise indicated.

the beet and upon the time in the life of the crop when the attack begins. After a beet plant has become infested with leaf-spot there is no known method by which the fungus can be destroyed without destroying or killing the beet leaves. It is evident, therefore, that control methods for leaf-spot must be preventive rather than curative. There are simple and effective means along the line of good agricultural practice by which the attacks of this fungus may be prevented, and it is the object of this bulletin to point out these preventive methods.

FIG. 2.—A young sugar-beet plant, showing the early stages of leaf-spot. (About one-third natural size.)

APPEARANCE OF LEAF-SPOT.

In considering any plant disease it is important to be able to recognize it in the field; otherwise, the success or failure of efforts toward prevention can not be known. The following brief description of leaf-spot as it appears in the field is therefore of importance in this connection.

The first distinct appearance of leaf-spot is a tiny point which is nearly white, indicating that the destruction of the tissue of the leaf has begun. These tiny spots, or points, so small that they are seen with difficulty by the unaided eye (fig. 2), increase more or less rapidly in size and assume a brownish color. These small brown and at first nearly round spots, which are scattered irregularly over the surfaces of the infested leaves and leaf stems and which may vary in number from less than a dozen to several hundred on the same leaf, are easily seen and to the casual observer are the first indication of the presence of the disease (fig. 3). The spots appear first on the outer and therefore older leaves of the beet, and if conditions are favorable for their development they soon cover these leaves, and the adjacent leaves are

similarly attacked. In this manner several of the outer or older whorls of leaves are infested, and as the adjacent leaves toward the center of the crown become older they are likewise attacked. Very rarely do the youngest center leaves show the characteristic brown spots which indicate the presence of leaf-spot, even when the disease is severe enough to kill the outer leaves. Consequently, the beet plants are seldom killed by this disease, although it frequently interferes seriously with their growth and development and with the quality of the roots.

FIG. 3.—A diseased leaf of a sugar-beet plant, showing the relative size, shape, and distribution of spots produced by the leaf-spot fungus. (About one-third natural size.)

The spots on the infested leaves continue to increase in size more or less rapidly, depending upon the conditions which influence the growth of the fungus, but they show, almost from the first, a distinct line between the discolored spot and the green surface of the leaf, as illustrated in figure 3. The margins of the spots are frequently tinged with a reddish brown or purple color. As the spots get older they assume, especially at the centers, an ashy-gray color, due to the development of the fungus and to the formation of spores. Usually the original spots remain distinct, but they often increase in size and number until their destructive influence extends over the entire leaf (figs. 4 and 5), finally causing the seriously affected leaves to die. As the older leaves die off under the influence of leaf-spot, new leaves are formed at the centers of the crowns. The consequence is that the crowns of the infested beets are pushed out, or elongated, as shown in figure 6. The affected spots do not usually break away, leaving holes in the leaf blades, as is the case with some leaf diseases of some other

plants, but the leaf often remains intact, even after it is dead from the effect of leaf-spot. The dead leaves usually become more or less brittle, especially if the atmosphere surrounding them is dry, and then the action of the wind, the cultivator, or other agencies may break or tear them (figs. 4 and 5). Frequently, however, the leaves, dead from the effect of this fungus, remain whole, droop, and lie flat on the ground, remaining attached to the plant even until the beets are harvested (fig. 7). At harvest time, however, the diseased leaves become more or less broken, so that portions of disease-infected leaves fall on the ground, where they remain over winter. A beet badly infested with leaf-spot shows, therefore, an elongated crown with a tuft of small green leaves at the top or center, surrounded by a larger or smaller number of whorls of brown dead leaves, as shown in figure 6.

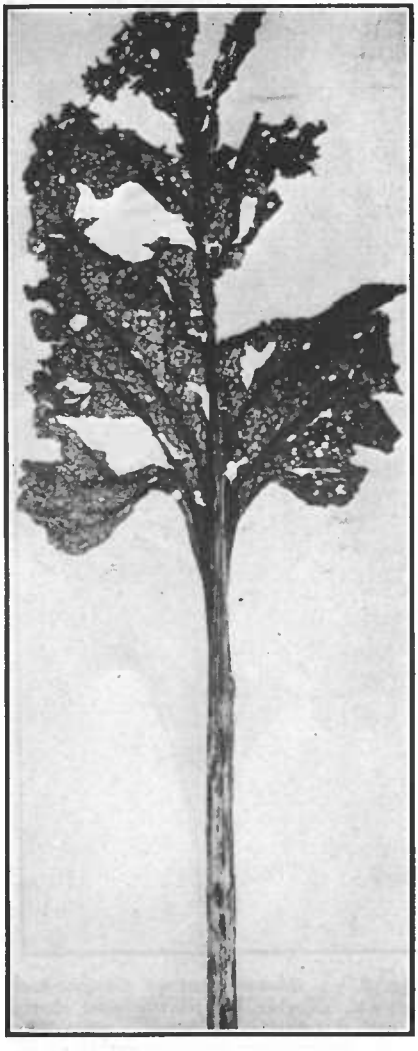

FIG. 4.—A leaf of a sugar-beet plant, showing leaf-spot on both the petiole and the blade. (About one-third natural size.)

In point of time, leaf-spot does not usually appear until midsummer. It may appear, however, at any time after the beets are a few weeks old until the approach of autumn, when the cool nights are unfavorable for the development of the fungus.

The greenhouse and field experiments and observations carried on by the writer since 1901 lead to the conclusion that if the Cercospora spores are present, the spots appear on the leaves within a few days after the plant and weather conditions are suitable for their development. It should also be noted that late plantings of beets are usually very much less liable to severe attacks of leaf-spot than early plantings in the same locality. This condition has undoubtedly been observed by all who have followed the development of leaf-spot in the field during a growing season.

THE LEAF-SPOT FUNGUS.

In order to understand how the leaf-spot organism reproduces itself and how it spreads from plant to plant and from place to place, a brief description of the fungus is here given.

Cercospora beticola, which produces the most common leaf-spot of the sugar beet, is composed of two parts—the vegetative part, which corresponds in a way to the vegetative part (root, leaves, and stems) of higher plants, and the reproducing bodies, called spores, which, for reproductive purposes, take the place of the seeds of higher plants. The spores are minute bodies, somewhat needle shaped, which are divided into from two to eight cells by means of cross walls, as shown in figure 8. These spores, which are usually light in color, are easily brushed off the surface of the leaves on which they are produced and are readily scattered by the wind or other agencies.

FIG. 5.—A leaf of a sugar-beet plant which has been entirely killed by leaf-spot. (About one-third natural size.)

When the spores germinate, they push out colorless tubes from one or several of the spore cells. These outgrowths from the cells of the spores, which are the beginnings of the vegetative parts of the fungus, elongate rapidly, forming threadlike structures. The growing tips of the fungous threads remain colorless, but the older cells become darker and darker until they are brown or black. These

threads push out new branches, which in turn elongate, divide into cells, and push out still other branches. These processes are repeated until a network of fine threads has formed, constituting the vegetative body of the fungus. While this growth is going on, the fungus must feed upon soluble material which is absorbed from the beet leaves through the walls of the fungous threads. The tendency of these threads is to push out in all directions at a nearly uniform rate if unobstructed, thus forming round or nearly round spots or areas of growth, as shown in figure 3. As these areas of growth in the leaf become larger, they sometimes become irregular in shape, owing to the presence of the leaf veins or other obstructions which prevent or retard the growth of the fungus in certain directions.

FIG. 6.—A sugar-beet plant showing elongation of the crown due to leaf-spot. (About one-fourth natural size.)

When a spore germinates upon the surface of a beet leaf, the threads produced penetrate the surface of the leaf and push their way among the cells of the leaf tissue, drawing nourishment from the living leaf cells and causing their death. The brown color of the diseased spots on the leaves is due in part to the dead brown cells of the leaf and in part to the color of the older fungous cells.

The main limiting factors in the growth of the fungus are food supply, moisture, and temperature. When the fungous spores lodge upon a beet leaf and the conditions for the growth of the fungus are favorable, the spores soon germinate and produce new spots, upon the surface of which a new crop of spores may be formed. In this manner the life cycle of the fungus is repeated over and over during the growing season, or until the climatic conditions render the reproduction and propagation of the fungus impossible. The length

of a single life cycle depends upon the favorable or unfavorable condition of the limiting factors mentioned. For example, with the approach of autumn and the consequent reduction in temperature, the cycles become longer and longer and the infections less and less numerous, until finally they cease.

DISTRIBUTION OF LEAF-SPOT.

Although there are certain localities where leaf-spot has not yet become sufficiently general and severe to do any appreciable damage to the sugar-beet crop, there are other localities where the fungus has found apparently very favorable conditions for its growth and development. This is especially noticeable in some parts of the semiarid region as well as in the more humid portion of the sugar-beet belt in the United States. The indications are that it is only a question of time when leaf-spot will be one of the factors to be reckoned with everywhere in the profitable production of this crop, unless practical means for its control are employed. When leaf-spot has become general in the beet fields in a given locality it remains year after year, doing sometimes more, sometimes less, damage, depending upon the climatic conditions and the cultural methods which affect the propagation and development of the fungus. Even if it were possible to eradicate leaf-spot from all sugar-beet fields in this country, it would probably be a question only of time when it would reappear, on account of the wide distribution of the fungus and its probable ability to exist on other host plants, both wild and cultivated, unless the use of practical, inexpensive control methods are continued. In the control of leaf-spot it is therefore important that attention be given to the methods and agencies by which the fungus and its spores are spread, as well as to the elimination of the fungus where the disease already exists.

The agencies instrumental in distributing Cercospora are numerous and varied in character, chief among which may be mentioned wind, water, insects, and man and other animals. These agencies may act independently, or two or more of them may work together. The distribution of the fungus from leaf to leaf on the same plant or from one beet to an adjacent plant may be accomplished by simple contact or by the action of the wind, the rain, or any of the other agencies mentioned. As already pointed out, the spores readily become dislodged from the mother fungus, and may easily be carried short distances by the wind. The indications are, however, that the spores are not carried long distances in this manner, although bits of diseased leaves may be blown from field to field. Water, especially when used for irrigating purposes, is an important agent in distributing leaf-spot from plant to plant and from field to field. Insects are also active agents in carrying the disease short distances, but

man and other animals are apparently the most effective agents in the distribution of leaf-spot. When diseased beets are cultivated, the spores become dislodged by the action of the cultivator or the horses' feet, and the spores may be blown about by the wind or carried on the implement, on the horses' feet, or on the driver's clothing. Care-

FIG. 7.—A field of sugar beets, showing the effect of spraying with Bordeaux mixture. The rows at the left of the stake were sprayed; those on the right were not sprayed.

less handling of the diseased beet tops in using them for feed has evidently spread the leaf-spot from field to field in many cases.

The spread of leaf-spot to distant localities not before used for sugar-beet production has generally been attributed to the presence of Cercospora spores on the seed. The fact that seed beets as well as factory beets may be and often are infested with leaf-spot make it comparatively easy for the spores to find their way to the seed balls,

the rough coats of which hold the spores during the process of transportation and until the seed is planted. While our investigations in this connection indicate that this is not the only means by which leaf-spot is spread, it is sufficiently common to warrant consideration in a study of control methods. The Office of Sugar-Plant Investigations of the Bureau of Plant Industry is making a careful study of beet-seed treatment for the destruction of fungous spores. It has been found that in new sugar-beet localities, where the conditions are favorable for the growth of the fungus, the beet plants are attacked sooner or later by the disease. While every possible precaution should be taken to prevent the spread of the disease, it is reasonably certain that its elimination can not be accomplished or its appearance in new localities entirely prevented by controlling its distribution on the seed. This is evident in view of the fact that the fungus attacks the garden beet, the stock beet, and other plants, both wild and cultivated.

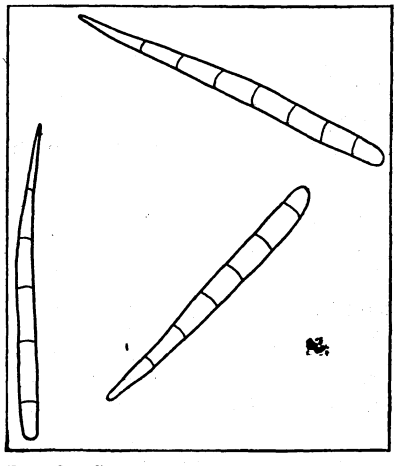

FIG. 8.—Spores of the leaf-spot fungus (*Cercospora beticola*) from sugar-beet leaves. August 20, 1912. (Greatly enlarged.)

EFFECT OF LEAF-SPOT.

The injurious effect of leaf-spot upon the sugar beet is fourfold. It reduces the tonnage, impairs the quality of the roots, increases the tare, and reduces the feeding value of the leaves. The amount of damage done by leaf-spot in a given field during any season will depend (1) upon the severity of the outbreak, (2) upon the time in the life of the plant that the disease appears, and (3) upon the subsequent weather conditions. Leaf-spot usually appears when a hot, dry period of two weeks or more is followed by moisture accompanied by continued high temperature, provided, of course, the leaf-spot fungus is present in the field. If these conditions prevail, so that the disease appears abundantly within six or eight weeks after planting, the growth of the beets will be retarded and a marked reduction in the tonnage will result. Under these conditions the amount of loss in tonnage will depend upon the subsequent weather conditions, as they may or may not favor the rapid development of the fungus. The more rapid the development of the fungus the greater the injury to the foliage, and consequently the greater the retardation in the growth of the roots and the consequent loss in tonnage of roots

and of sugar per acre. If, however, the disease does not appear until late in the growing season—that is, from three to four weeks before the beets are harvested—the loss in tonnage from the effects of leaf-spot will be slight. The reverse is true in regard to the effect of leaf-spot upon the sugar content of the beets. While the beet begins to store some sugar very early in its existence, the rapidity of storage increases with the age of the beet. If, therefore, leaf-spot appears early, is severe for a time, and then by some means is retarded in its development during the latter part of the growing season, the sugar content of the beets may reach a normal or nearly normal percentage. The yield of sugar per acre under these conditions will be reduced only because of the smaller size of the beet roots. On the other hand, if the disease appears late in the growing season and continues its injury to the foliage until the beets are mature, there will be a marked decrease in the sugar content of the beets and a corresponding loss in the sugar per acre, although the tonnage may not be appreciably lessened. If the fungus begins its destruction of the foliage early and continues it until late in the growing season, there will be a loss in both tonnage and sugar content of the beets. Hence, leaf-spot may reduce the tonnage only, it may reduce the sugar content only, or it may, and usually does, reduce both the tonnage and the sugar content of the beets. It has been found by the writer and others, that a limited amount of injury may be done to the beet foliage with no appreciable effect upon the size or quality of the roots. It is possible, therefore, to have such a light attack of leaf-spot that no appreciable injury results, but if the attack of Cercospora is severe enough to be at all injurious it will reduce the amount of sugar per acre.

The effect of the disease upon crown development is very marked. As has already been noted, it is the older and therefore the outer whorls of leaves that are first attacked by leaf-spot, while the young leaves in the center of the crown usually remain in a healthy, growing condition. When the older leaves die under the influence of leaf-spot, the crown of the beet is drawn out or elongated, as shown in figure 6. Inasmuch as the beet crown contains a high percentage of salts taken up from the soil, which tend to keep the sugar from crystallizing in the mill, all beet-sugar companies require that the crowns be cut off at the point of the lowest leaf scar. When the crowns are unduly elongated the result is a heavy tare upon the beet crop, since a large amount of growth has gone into the elongated crown instead of into the root proper. This is not an entire loss, since the beet crowns, together with the leaves, form an excellent stock feed. But since sugar beets are grown primarily for the money value of the root proper, the undue elongation of the crowns causes considerable money loss to the grower. The amount of elongation and consequent loss due to leaf-spot depends upon the severity of

the attack and upon the time in the growth of the plant that the disease appears.

As already stated, beet tops—that is, the crowns and leaves together—form a very important stock feed. In connection with other feeds, beet tops form one of the most valuable stock feeds produced on the beet farm, especially for dairy cows. Any injury, therefore, that tends to decrease the quantity or to reduce the quality of this material is a serious loss to the beet grower. While leaf-spot tends to elongate the crown and thereby to increase the percentage of crown compared with the root yield per acre, the total quantity of feed produced from badly or even moderately infested beets is very greatly lessened by the effects of leaf-spot upon the leaves. Aside from the effect that leaf-spot has upon crowns, the leaves are rendered brittle and frequently die before they are mature. As a result of the brittleness of the leaves they are more or less seriously broken in handling at harvest time, with the result that a large part of the diseased leaf material remains in the field and is lost, so far as feeding it to stock is concerned. As to their feeding value, it is safe to say that the injured leaves have lost at least 50 per cent of their value. This is a source of loss that is frequently overlooked, but it is none the less important. Estimating the feeding value of vigorous beet tops at $5 per acre, which is below their real value, the total value of the tops in this country would be, for the 814,988 acres harvested in 1921, $4,074,940. An average loss of even 10 per cent of the feeding value of the tops due to leaf-spot would amount to more than $400,000, to say nothing of the greater loss occasioned by the reduction in the tonnage and in the sugar content of the roots.

CULTURAL METHODS OF CONTROL.

The most satisfactory and practicable methods known at present for reducing leaf-spot are deep fall plowing and crop rotation. Inasmuch as crop rotation is the "balance wheel" of good farming and must be practiced in order to obtain the most profitable results, regardless of the presence of leaf-spot, this disease and many other pests may be controlled and other advantages gained by crop rotation without extra expense and labor. If the rotation system is wisely planned and carefully and thoroughly executed, better crops of all kinds will result and many pests, including this fungus, will be eliminated or at least reduced below the point of serious injury, provided the fungus is not returned to the field in the manure, on the seed, or in some other way.

The principles of disease control by means of crop rotation are based upon the fact that certain pests, like this fungus, can thrive only on certain kinds of plants. Therefore, when the crops are

changed and the food supply thereby cut off, the pests must perish or be greatly reduced in number. It must be remembered that the most profitable crop rotation does not consist merely in changing the crops around from year to year regardless of the relation of the crops to each other, but that the central aim in all crop-rotation systems should be to leave each field in better tilth, better physical condition, and reasonably free from pests at the end of each rotation cycle.

No hard and fast rotation system can be laid down for any community, but the most profitable system must be worked out for each farm and, indeed, for each field. There are certain general principles, however, that should be borne in mind in this connection in order to accomplish the most satisfactory results. For soil improvement there should be at least one leguminous crop in each rotation cycle. To this class of plants belong the clovers, alfalfa, peas, beans, etc. There should be also a sufficient number of live stock, especially milk cows, on each farm to utilize the beet tops and roughage and to supply the desired quantity of stable manure, which, in addition to green crops plowed under, will furnish the necessary amount of humus to the soil. The conditions resulting from this treatment, if the soil is properly handled, will make the succeeding crops more vigorous and capable of offsetting, in some measure at least, the effects of any pests that may appear. Again, the successive crops in any rotation should be so selected and arranged that no two upon which the same pest may thrive will be grown in succession. The beet-leaf fungus *Cercospora beticola* has not been known to thrive upon the small grains, corn, clover, alfalfa, cowpeas, beans, and many other plants suitable for rotation with sugar beets. It is apparent, therefore, that crop rotation properly carried out offers a satisfactory means of eliminating, or at least of keeping in check, this pest, which, if allowed to gain headway, will turn an otherwise profitable crop of sugar beets into a serious loss to the grower. Experience and observation teach that not more than two successive crops of beets should be grown in any rotation cycle. It is true that three or more successful crops of beets have been grown in succession in some instances, but for obvious reasons it is a bad practice and should be avoided. Many successful growers never follow beets with beets. In one locality where leaf-spot had formerly been a serious pest, a system of crop rotation has been adopted in which beets seldom follow beets, with the result that leaf-spot is no longer feared. An examination of the beet fields in that locality late in the growing season showed practically no leaf-spot in any of the fields where a few years before a field not more or less seriously injured by leaf-spot was an exception.

The length of time that a field infested with leaf-spot should be in crops other than beets in order to insure the destruction of the leaf-spot fungus and spores appears to depend somewhat upon climatic conditions and upon the manner in which the soil is handled. One field that came under the writer's observation was so badly infested with leaf-spot that the crop was not harvested. The field was then seeded to alfalfa. At the end of two years it was fall plowed to a depth of 12 to 14 inches and subsequently put into beets for two successive years. Very little leaf-spot appeared either the first or second year that the field was in beets, following the two years in alfalfa. This and other examples indicate that, under some conditions at least, an interval of two years will reduce leaf-spot below the danger point. It is wise, therefore, in planning a rotation cycle to arrange for two or more years in other crops before returning to beets. Furthermore, it should be noted that the best all-around results are obtained when the rotation period covers three or more years.

Another method which under some conditions has given positive results in the control of beet leaf-spot is that of deep fall plowing. The writer has found by experience that deep fall plowing of beet land has a marked effect in reducing the amount of leaf-spot in the succeeding crop. For example, a field where leaf-spot was very injurious to the beet crop was plowed to the depth of 14 inches in November. It was again planted to beets the following year, with the result that very little leaf-spot appeared, while the shallow-plowed land in the same locality which was planted to beets showed a destrictive amount of leaf-spot. The plowing should be done with a moldboard plow, so that the surface soil, which contains the fungous spores, is turned under completely. On general principles of good farming an occasional deep fall plowing is beneficial to certain soils. It is not recommended, however, as a general method of controlling leaf-spot, to the exclusion of crop rotation, and should be used for this purpose only in case it is absolutely necessary to follow infested beets with another crop of beets.

SUPPLEMENTAL AIDS IN THE CONTROL OF LEAF-SPOT.

SPRAYING.

The cost of spraying, together with the extra labor involved and the possible lack of thoroughness in the work, makes it questionable whether spraying should be considered as a control measure for leaf-spot. However, there may be conditions under which spraying would be advantageous. It has, therefore, been considered best to refer to this method in this connection. The writer has demonstrated repeatedly that leaf-spot may be controlled almost perfectly

by the proper use of Bordeaux mixture. The most important question in this connection is whether the cost of spraying will exceed the advantages to be gained by this method of control. The formula for Bordeaux mixture used by the writer in his experiments and demonstration work with leaf-spot was 4–4–50; that is, 4 pounds of copper sulphate, commonly called bluestone, 4 pounds of slaked lime, and 50 gallons of water.[2] After ascertaining that this preparation would in no way injure the beet foliage, the next point to determine was the proper and most effective time to begin the spraying. In order to settle this point, a field which had been in beets the preceding year and which was badly infested with leaf-spot was selected, prepared, and planted. A number of plats to be sprayed were then laid off on one side of the field in such manner that the sprayed plats would be bordered on three sides by beets not sprayed. The first plat was sprayed as soon as the beets were thinned and while they had from four to six leaves only. Two weeks later the same plat was sprayed again and another plat of the same size adjacent to the first was sprayed for the first time. After another interval of two weeks the first and second plats were again sprayed. This operation was repeated until leaf-spot began to appear on the unsprayed beets. The last plat added to the experiment had a few spots on the leaves due to *Cercospora beticola* when sprayed for the first time. All the plats that had been sprayed were subsequently resprayed at intervals of two weeks throughout the season; that is, until the nights turned cool and the danger of the spread of the disease was over.

When the spraying was discontinued in the autumn none of the plats that had been sprayed had any perceptible amount of leaf-spot, while the unsprayed beets on the three sides of the sprayed plats were infested to such an extent that from one-half to two-thirds of the leaves of each beet were entirely brown and dead. In the last plat added to the experiment, that is, the one in which the leaves had an occasional tiny Cercospora spot, the disease did not advance, and it was just as good from the standpoint of tonnage and quality at the end of the season as the other plats sprayed, while the unsprayed plats were badly damaged in both tonnage and quality. This experiment was repeated several seasons and always gave similar results, varying only in the amount of damage done by the disease to the unsprayed beets. In some cases the yield of the unsprayed beets was only 50 per cent as great as the yield from an

[2] Bluestone is best dissolved by placing it in a gunny sack and suspending it in a given quantity of water in a wooden tub or barrel. A metal container should not be used. The lime should be stone lime of good quality and freshly slaked. These solutions will keep a long time if they are not mixed. In preparing Bordeaux mixture the two solutions are each diluted and then poured at the same time into a tub or barrel and vigorously stirred. To this mixture enough water should be added so that the proportion of bluestone, lime, and water will be 4 pounds of bluestone and 4 pounds of lime to each 50 gallons of water. It should be used as quickly as possible after it is prepared.

equal area of sprayed beets. This was the result if the disease appeared early and was severe in its attack until past midsummer. In other cases the sugar content of the unsprayed beets was 5 per cent lower than in the sprayed beets. The greatest reduction in sugar content occurred when the pest continued to develop until nearly harvest time, showing that the amount of damage done by leaf-spot depends upon the time that the disease appears and upon the subsequent weather conditions. These experiments prove that leaf-spot may be controlled by the use of Bordeaux mixture and that spraying before leaf-spot appears is a waste of time and material.

The cost of spraying will depend upon local conditions. The price of bluestone is subject to some fluctuations, but it can usually be had in bulk at from 8 to 10 cents per pound. One barrel, or 50 gallons, of the spray containing 4 pounds of bluestone should spray at least one-half acre. At an average cost of 10 cents per pound, the bluestone required for 2 barrels of spray, sufficient for an acre, would be 80 cents. The cost of the lime is so slight that it may be ignored. Two men, a team, and a 4-row sprayer should cover from 5 to 10 acres a day, depending upon the convenience of the water supply and the efficiency of the sprayer. The daily labor cost for men and team should not exceed $6. Taking 8 acres as an average day's work, the labor cost per acre should not exceed 75 cents for each spraying. Taking six as the minimum number of sprayings that would be required in any season, the cost per acre for the season would be for bluestone $4.80 and for labor $4.50, making a total of $9.30. At a flat rate of $5 per ton for beets, it would therefore require an increased yield, due to the spraying, of nearly 2 tons per acre to offset the cost of material and labor. Local conditions must determine whether putting this additional expense upon the crop would be justified. It should be added that the spraying to be effective must be thoroughly done (fig. 9). Both the upper and the lower surfaces of the leaves must be completely covered with the mixture. Spraying the upper sides of the leaves only or a partial spraying of both the upper and the lower sides of the leaves will not be effective in controlling leaf-spot. In no case, therefore, should spraying for leaf-spot be undertaken unless it can be done thoroughly and at the proper time.

In certain localities there are difficulties in the way of thorough spraying that should be given due consideration before the work of spraying for leaf-spot is undertaken. For example, in irrigated sections it is sometimes necessary to irrigate the beets just at the time when the spraying should be done to be most effective. Furthermore, the irrigation ditches across the fields are a hindrance to the work. Either the ditches must be plowed in each time before spraying or much time will be lost in turning at each cross ditch. In

humid regions these difficulties are not encountered, but in localities where showers are frequent the spray may be washed off by rain before the mixture has had time to dry on the leaves. In such cases respraying is necessary, and should be done immediately after the rain is over. If spraying is undertaken, it must be remembered that it is a preventive and not a cure. For this reason the leaves must be covered as soon as the disease begins to appear, in order to make further infection impossible.

MOISTURE.

A constant and uniform supply of moisture in the soil has a beneficial effect in retarding an outbreak of leaf-spot. Moisture reduces the temperature of the soil and of the atmosphere surrounding the

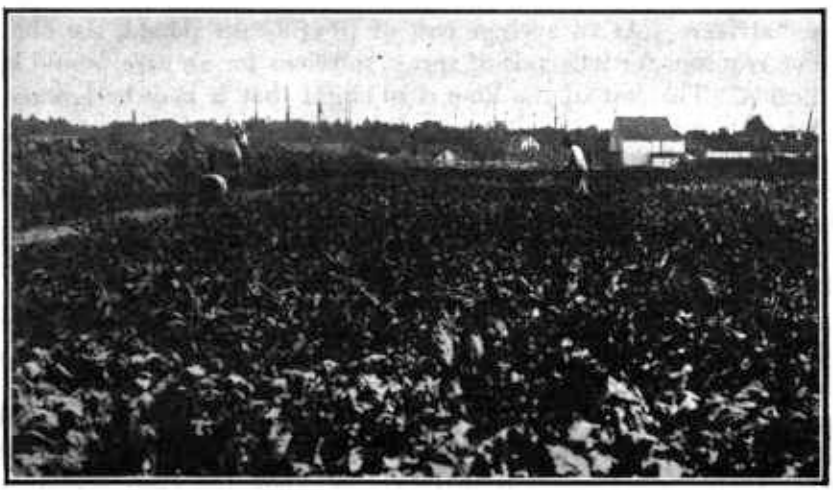

FIG. 9.—A field of sugar beets in 1901, showing the method employed in tests of spraying as a means of controlling leaf-spot.

beets and also prevents the leaves from wilting. It is noticeable that a slight reduction in temperature will retard the development of Cercospora and the production of spores. It is noticeable also that when a beet wilts it is generally the outer or older leaves that wilt first, just as it is generally the outer or older leaves that show the first spots. Beets growing close to irrigating ditches and in other places favorable to a constant and uniform water supply are, as a rule, much less severely attacked by leaf-spot than beets growing under conditions which show marked variation in the supply of soil moisture.

As previously noted, severe outbreaks of leaf-spot usually have been preceded by a long dry period followed by a renewal of the moisture supply. The dry period is usually long enough to cause a wilting of the outer beet leaves. While there seems to be some rela-

tion between the wilting of the leaves and an outbreak of leaf-spot, the exact connection has not been determined. As a control method, however, it is safe to say that a constant and uniform supply of soil moisture sufficient at all times to prevent the wilting of the leaves will aid in retarding an outbreak of leaf-spot. Every effort should therefore be made to put the soil in the best possible shape for receiving and holding moisture by plowing the ground to a good depth, by supplying an adequate amount of humus, and by frequent and thorough subsequent cultivation.

Under certain conditions moisture gathering and holding substances, such as common salt, have appeared to be of value in preventing an outbreak of leaf-spot. In some experiments along this

FIG. 10.—A field of sugar beets, showing the effect of salt treatment. The ground to the right of the stake was treated with 1,000 pounds of common salt to the acre; the area at the left was not treated.

line the writer found that 1,000 pounds per acre of common salt applied just before planting and thoroughly worked into the surface soil reduced the severity of leaf-spot to a marked degree, as shown in figure 10. However, this treatment had no decided effect upon leaf-spot if the period of drought preceding the outbreak of the disease was exceptionally long and severe. In irrigated sections frequent waterings will be beneficial in warding off leaf-spot, but unless the physical condition of the soil is such that it has a good water-holding capacity it will be practically impossible to irrigate often enough to prevent the development of the fungus. In fact, frequent waterings with a low water-holding capacity of the soil seem to aid rather than retard the development of leaf-spot.

Having given attention to crop rotation as a means of starving out the fungus, and having plowed the ground to a good depth in the fall so as to place the fungous spores where they can not come in contact with the beet leaves, care must be taken not to bring the fungus into the field on the seed, on the implements, in the manure, or in any other way. It is also essential that the growing conditions be kept as nearly uniform as possible.

In no case should any one possible method of controlling leaf-spot be used to the exclusion of the other methods, but each should be employed in its turn, from crop rotation through the proper preparation of the seed bed, clean seed, clean implements, and good growing conditions, until the crop is made and laid by.

DISPOSING OF BEET TOPS.

Theoretically, it should be feasible to remove the leaf-spot from a field by carefully gathering and removing the diseased beet leaves; but since the diseased leaves are more or less torn and scattered during the harvesting process, it is practically impossible to accomplish this result. The usual methods practiced in the handling of beet tops are the pasture method, the hauling-off method, and the plowing-under method. Cattle or sheep may be used in pasturing the tops after the roots are removed from the field. This should be done only when the soil is in such condition that it will not be injured by trampling. Care should be taken also that this method does not result in scattering the disease to fields to be used the following year for beets. This can be accomplished by not allowing the stock to enter the fields that are to be used for beets the following year while pasturing on the beet tops or until several days after they have been taken off the beet-top pasture. If the tops are hauled to the feed yard or silo, care should be taken to allow none of the diseased leaves to be scattered on the ground to be used for beets the following year. Beet tops are far too valuable as stock food to be wasted and should be hauled to the feed yard or silo, where they should be properly stored and eventually fed in racks. This is not only economical, but it keeps the diseased leaves from blowing about and puts the manure where it can be handled in the safest manner and to the best advantage. Beet tops, if plowed under, will add some humus to the soil. Under some local conditions this may be the best method of disposing of the tops. If this method is used, the plowing should be done in the fall in a thorough manner, so that all the leaves will be turned under to a depth of 10 inches or more.

DISPOSING OF THE MANURE.

It has been found that the leaf-spot fungus will be destroyed in one or two years if beets are not grown in the field where it is present or if the infested ground is deeply plowed in the fall. It becomes a sim-

ple matter, therefore, to prevent the propagation of the leaf-spot fungus by applying the manure to the land one or two years in advance of the beet crop. This is not only a wise precaution from the standpoint of controlling leaf-spot, but it is also good farming, since sugar beets do much better on well-manured ground to which the manure was applied one or two years in advance of the beet crop.

SUMMARY.

(1) *Leaf-spot may be controlled on a commercial scale and in a practical and inexpensive manner by a carefully planned and thoroughly executed system of crop rotations combined with deep fall plowing, provided the fungus is not brought into the field on the seed or by the wind or other agencies, and provided the best and most uniform growing conditions are maintained.*

(2) Leaf-spot may be controlled by thorough and timely spraying with Bordeaux mixture.

(3) A proper and uniform supply of soil moisture, spraying, and the proper disposition of beet tops and stable manure are important aids in the control of leaf-spot.

(4) The principal agencies in the distribution of the leaf-spot fungus are wind, water, insects, and man and other animals.

(5) Leaf-spot tends to reduce either the tonnage or the sugar content of the beet, or both, depending upon the time, duration, and severity of the attack.

(6) Leaf-spot seriously injuries the feeding value of beet tops.

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